Combination of Atomic Force Microscopy and X ray beam :

experimental set up and objectives

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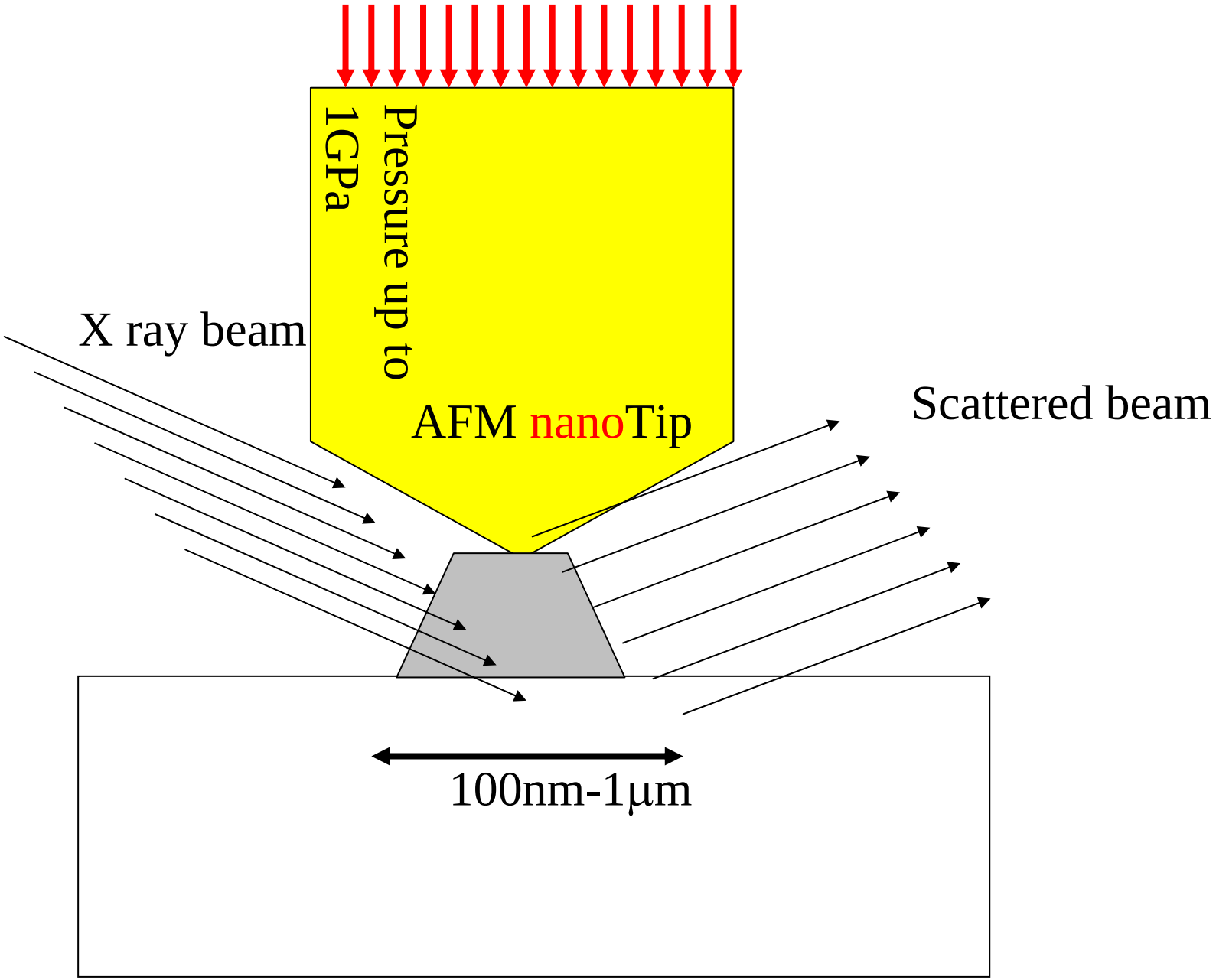
Nanotribology
tip surface interaction

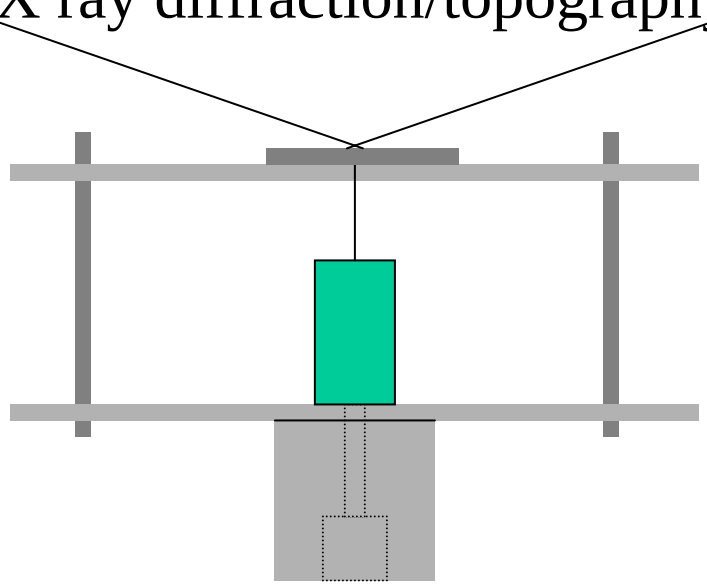

Pressure up to
1GPa
X ray beam
AFM nanoTip
Scattered beam
100nm-1μm

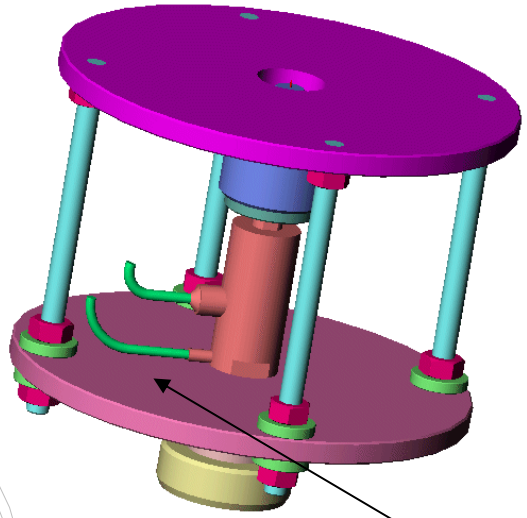
X ray and tip:

first exercise….

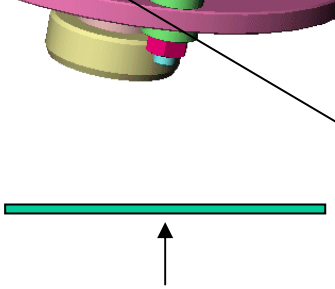
Designed of a very simple machine (2002)

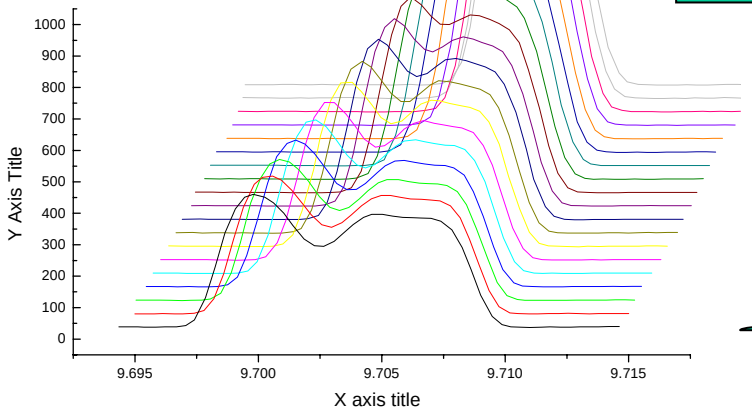
combining surface pressure (not local enough, poor control)
and X ray diffraction/topography (D19 coll. J Hartwig/J. Baruchel)

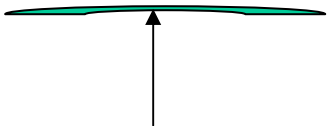




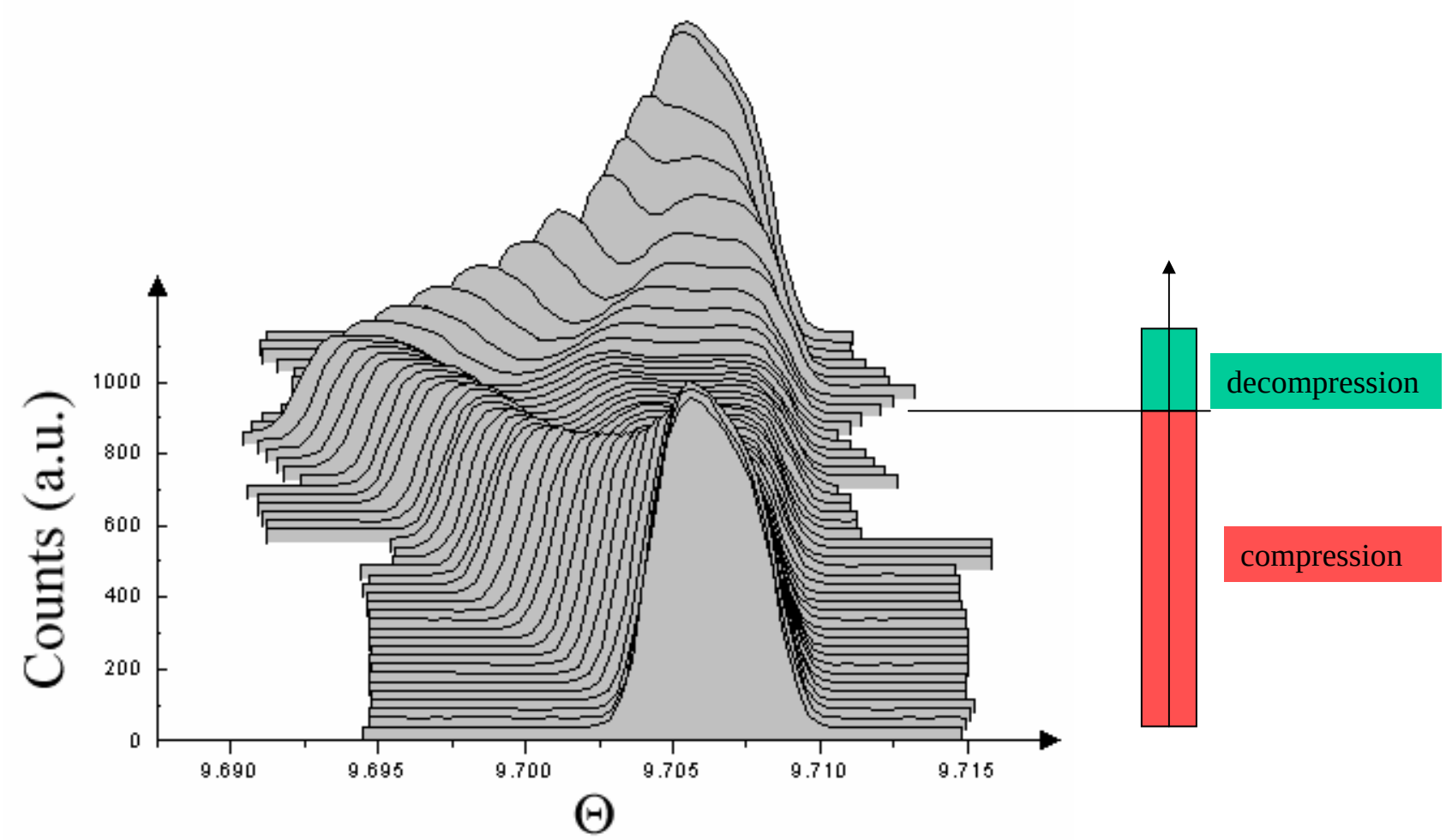
Piezo
20 μm total range







Bragg peak change
during pushing
on a 300 μm
thick Si wafer

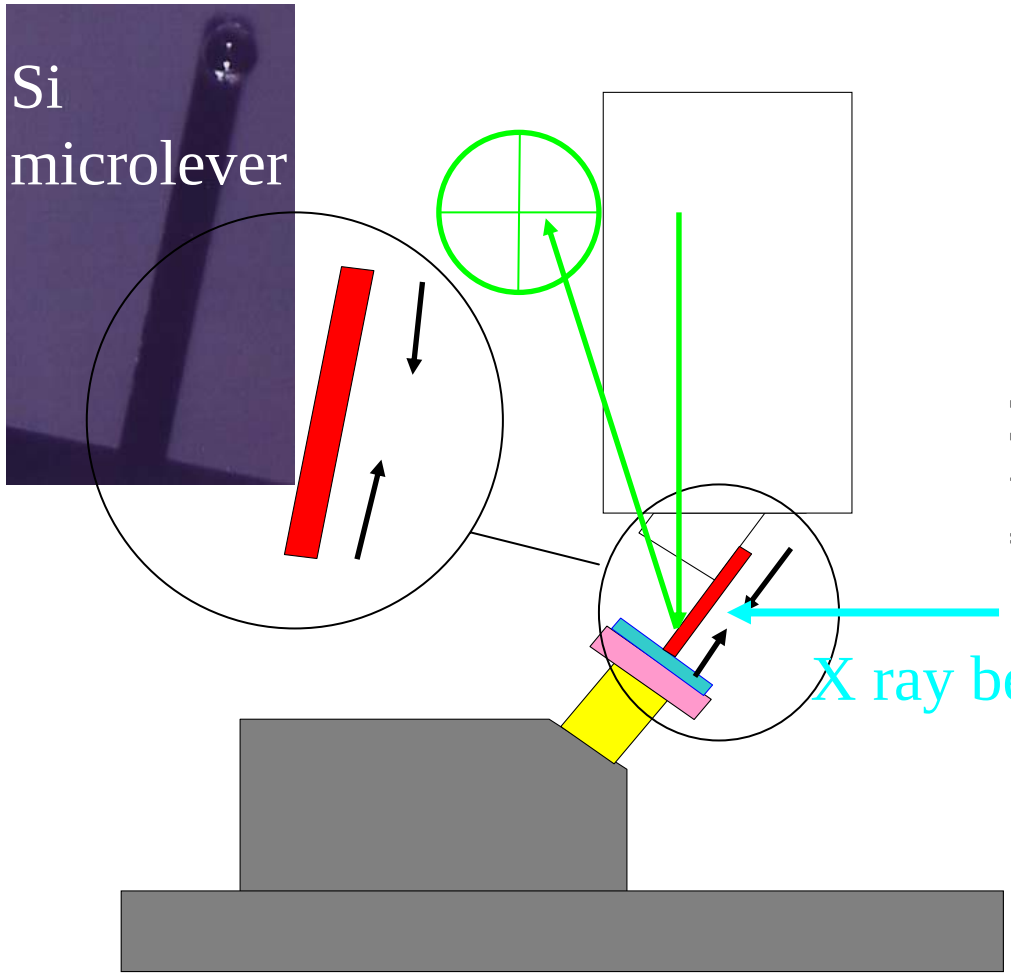


Direct contact

Pulling: adhesion

Pushing: pressure

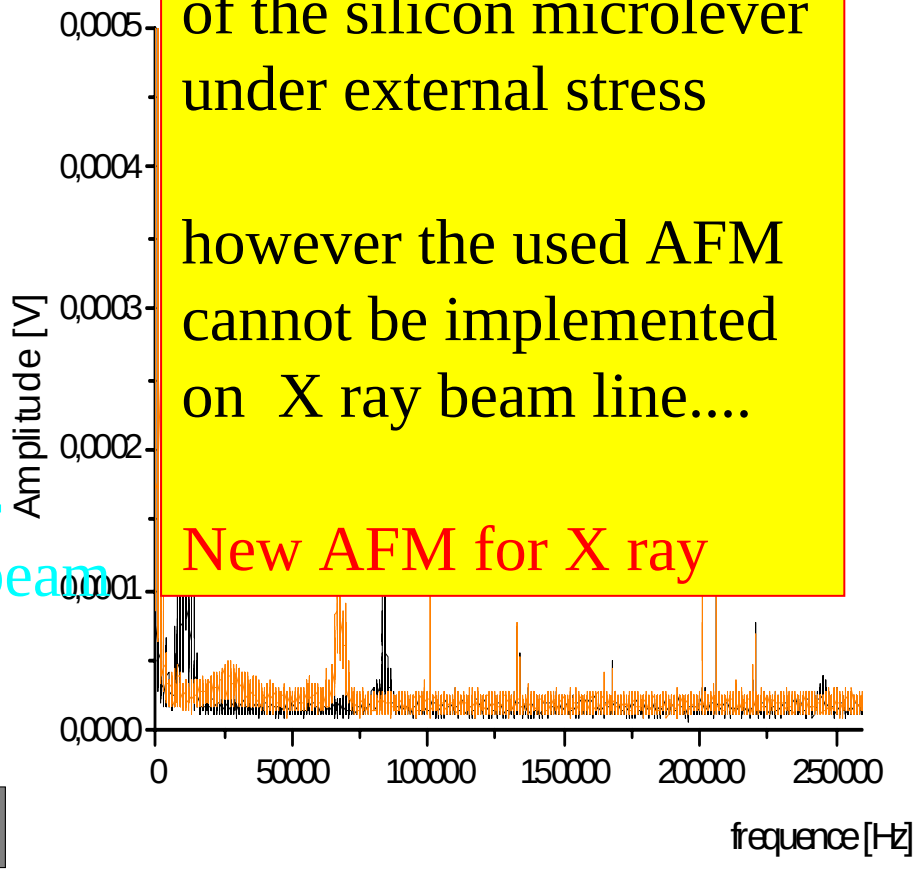
test of AFM deformation of a MEMS: mechanical Euler instability



probe deformation
of the silicon microlever
under external stress

however the used AFM
cannot be implemented
on X ray beam line....

New AFM for X ray



Brownian motion:
Vibrational characteristics changed by applied stress

X ray and tip:

but….

Implementation of current AFM on beamline not easy….

X ray and tip: some interests….

1-Mechanics: deformation and structure

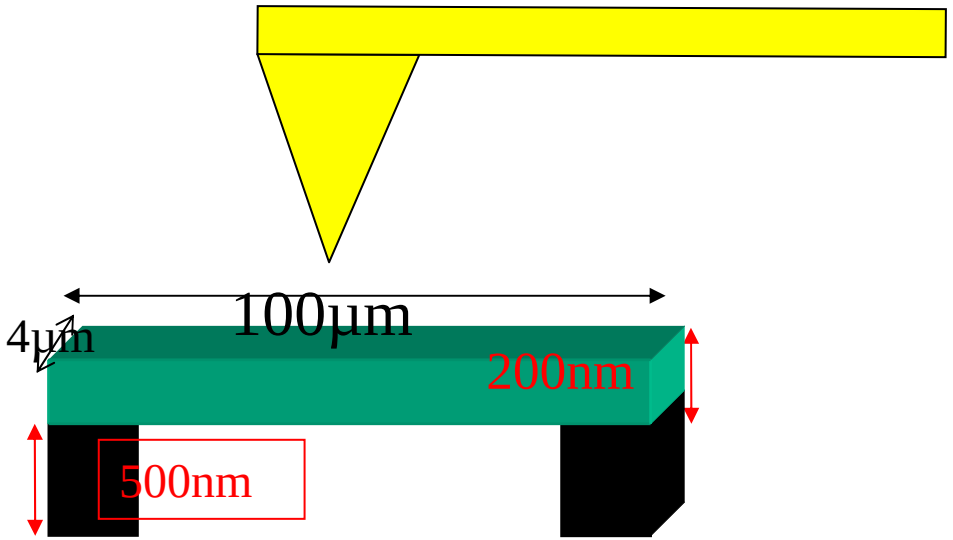
2-Local detection of X ray induced charge

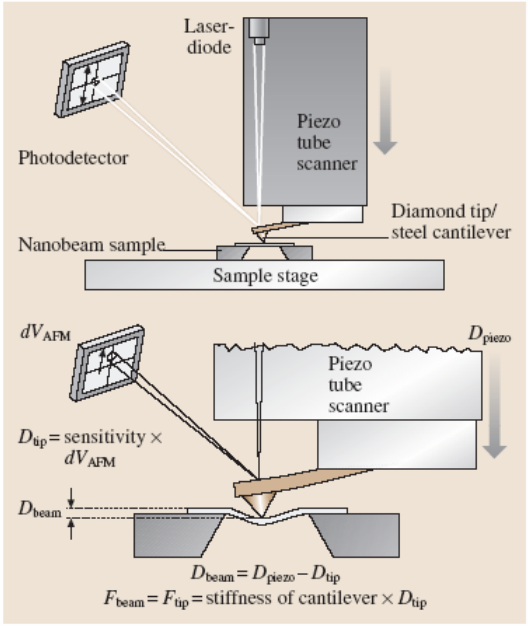
3-Positioning of nanoobjects

4-mechanical effect of X ray….2 hbar k

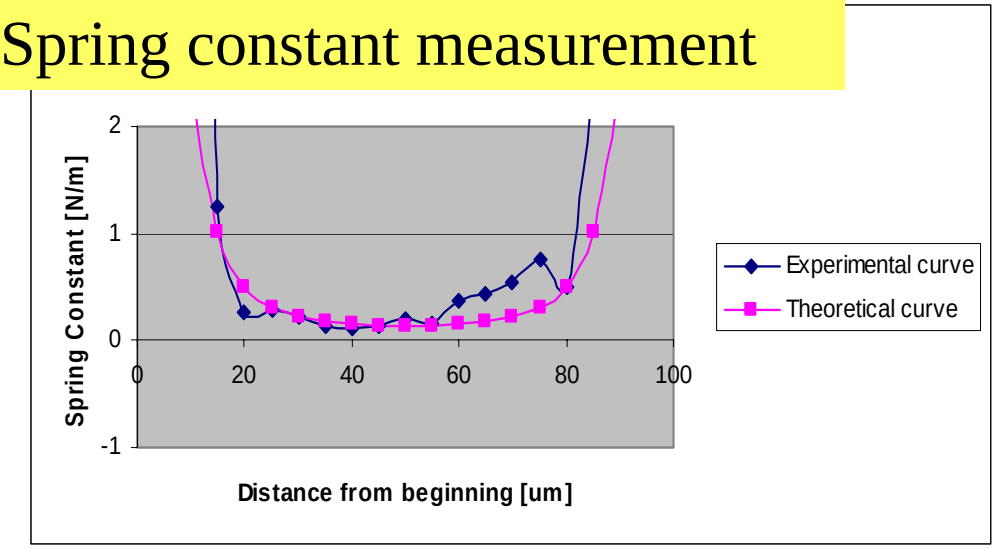
Few photons but large k...

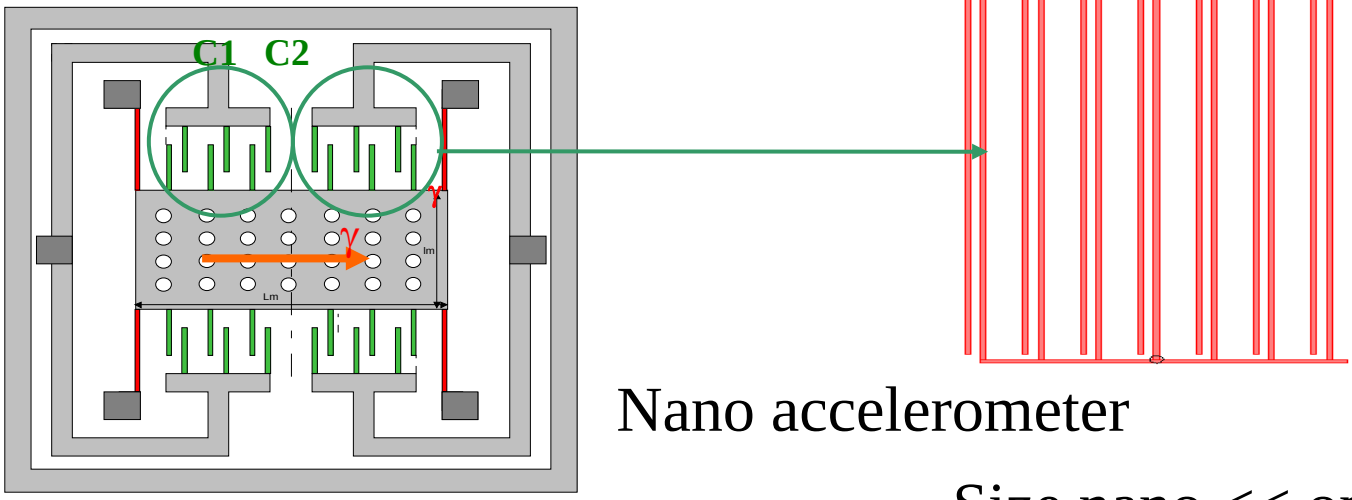
Estimation of the spring constant of a double fixed micro-beam





Spring constant measurement

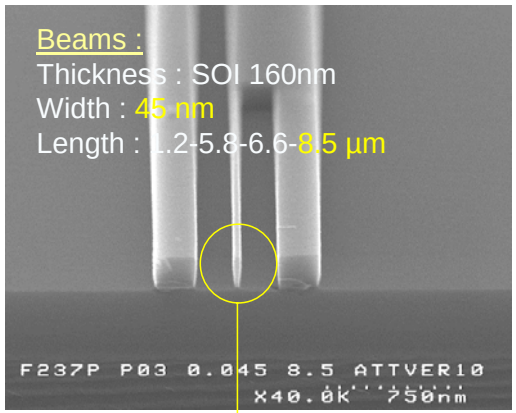


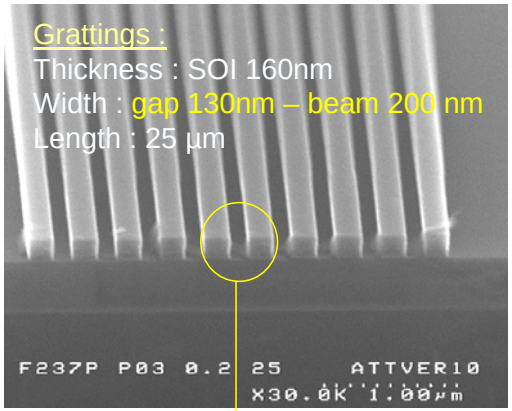


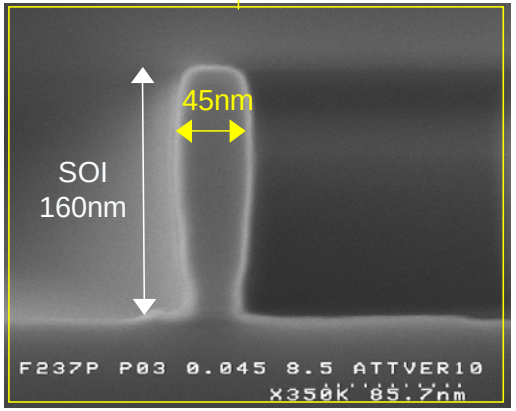
Nano accelerometer

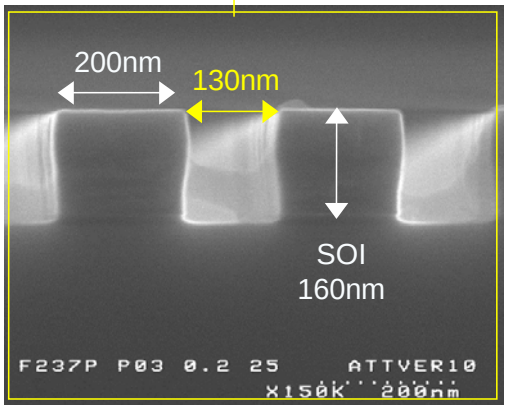
Size nano << optical wavelengt

diffraction of light



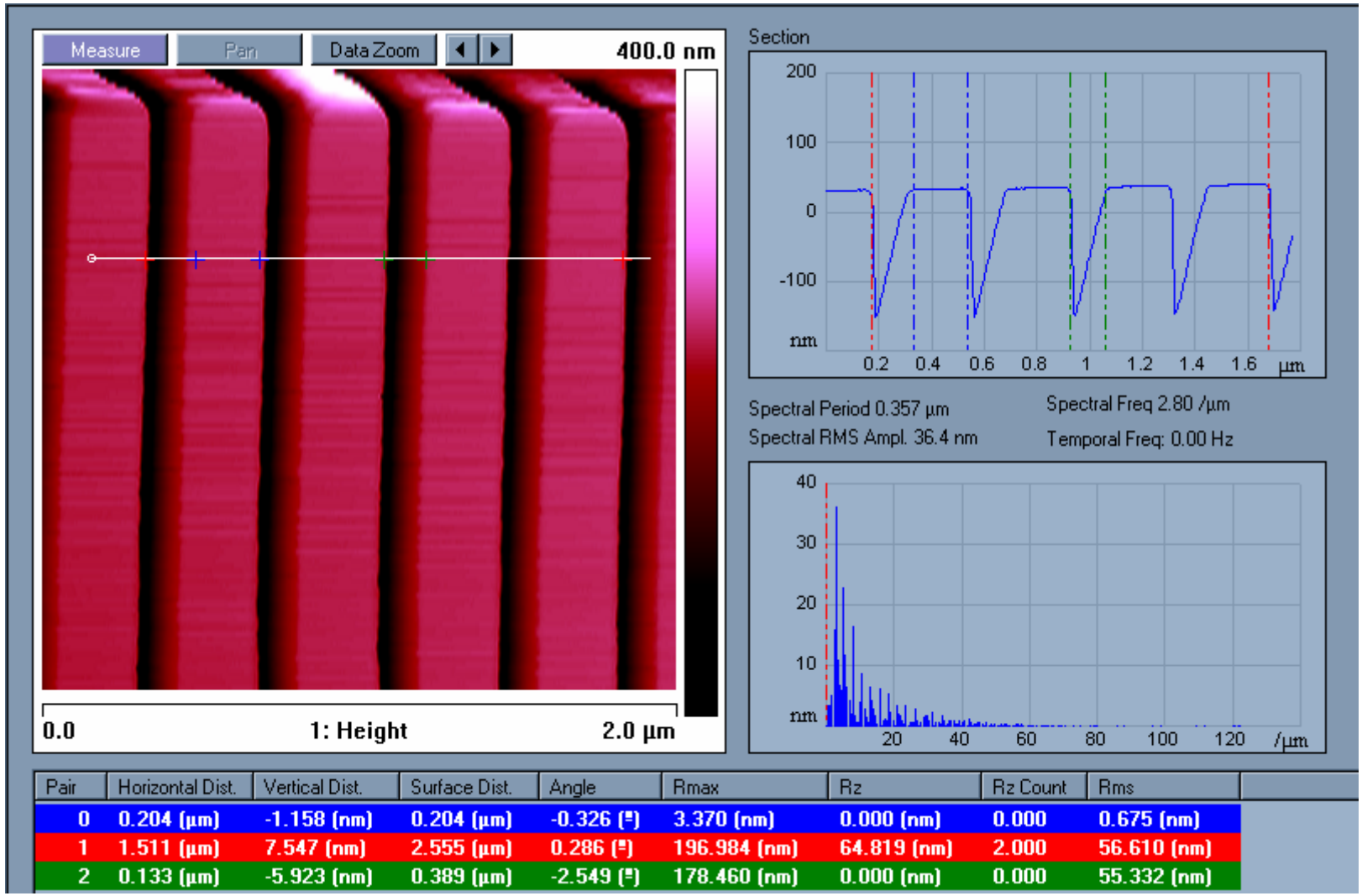






Images MEB
LETI CEA Grenoble

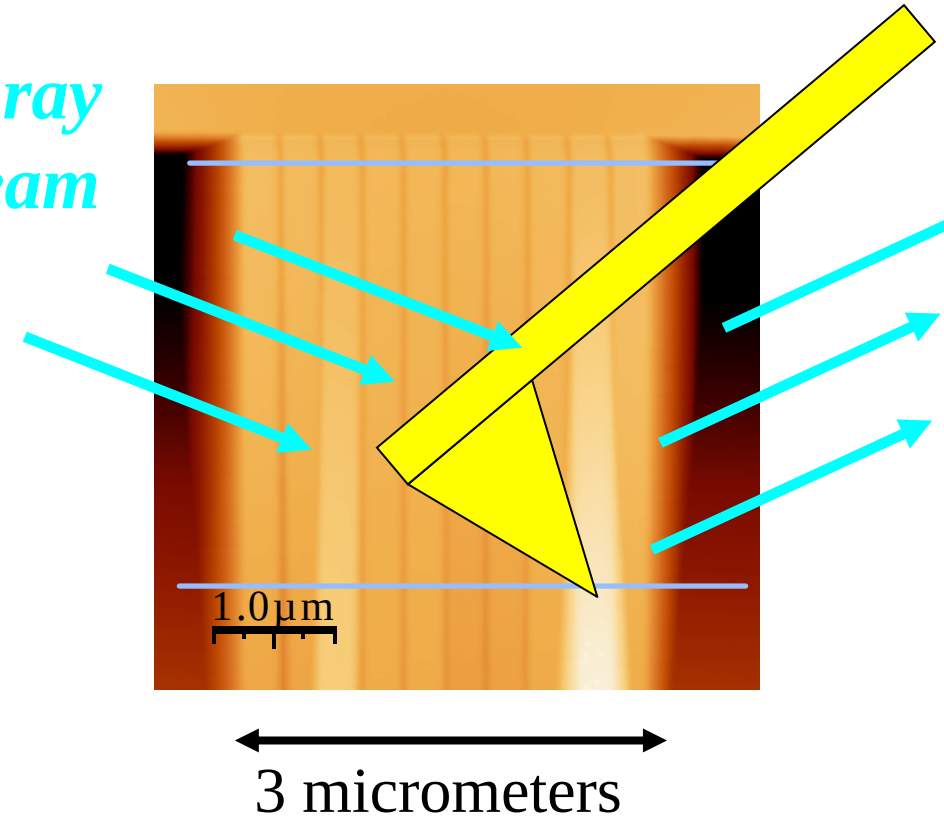
AFM imaging of NEMS: true nanostructure coll. ESRF-LEPES-LETI Grenoble



Pair	Horizontal Dist.	Vertical Dist.	Surface Dist.	Angle	Rmax	Rz	Rz Count	Rms
0	0.204 (µm)	-1.158 (nm)	0.204 (µm)	-0.326 (°)	3.370 (nm)	0.000 (nm)	0.000	0.675 (nm)
1	1.511 (µm)	7.547 (nm)	2.555 (µm)	0.286 (°)	196.984 (nm)	64.819 (nm)	2.000	56.610 (nm)
2	0.133 (µm)	-5.923 (nm)	0.389 (µm)	-2.549 (°)	178.460 (nm)	0.000 (nm)	0.000	55.332 (nm)

Deformation of NEMS:
nano-electro-mechanical-system

X ray beam

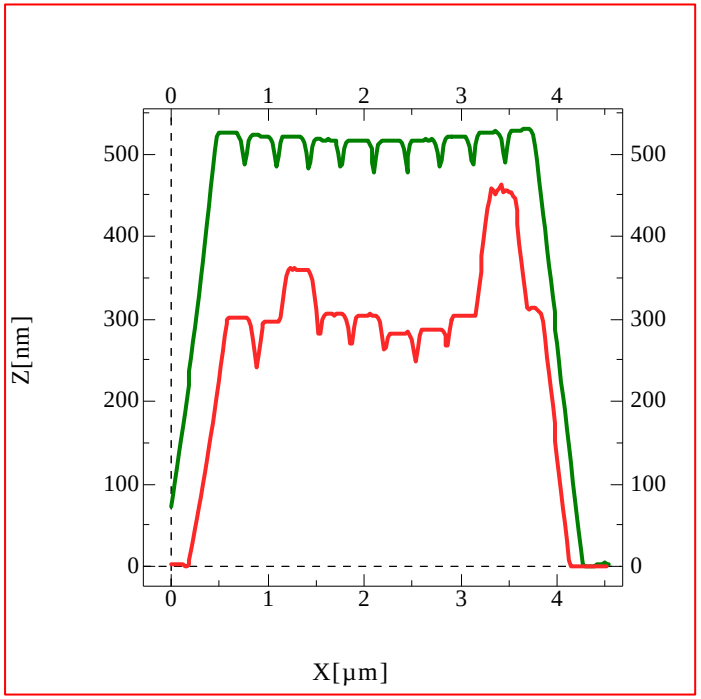


3 micrometers

AFM Image

NOT optical….

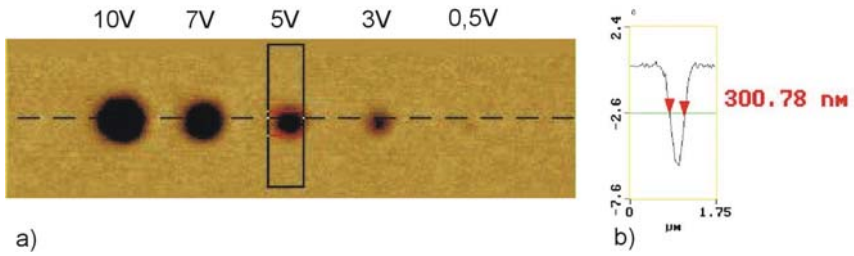
Signature of in situ real time deformation
at nanoscale in X ray scattering



AFM Charge detection by force

easily down to a few electrons!!!

EFM Detection of 20-40 électrons
in dry air at RT in semiconductor nanostructures

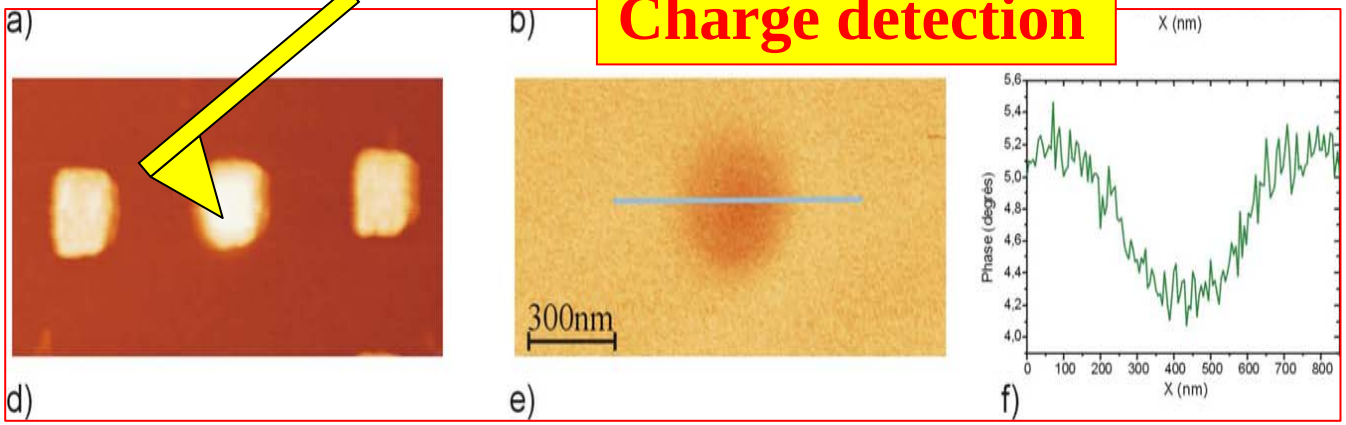


Charging experiments on 7 nm SiO_2
(injection time: 10 s)

Ge dots on silicon wafer: charge tip injected by contact

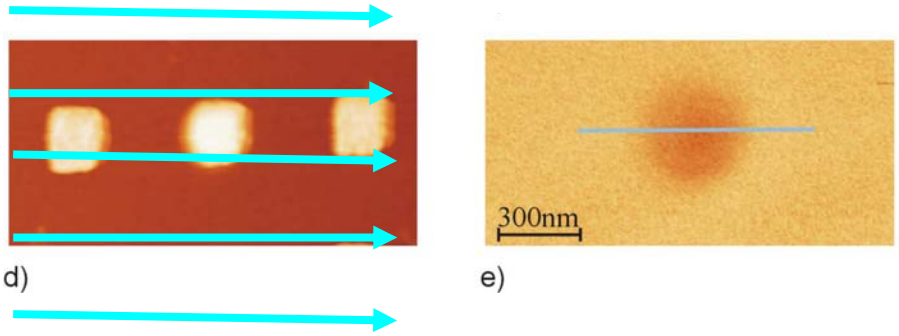
Height

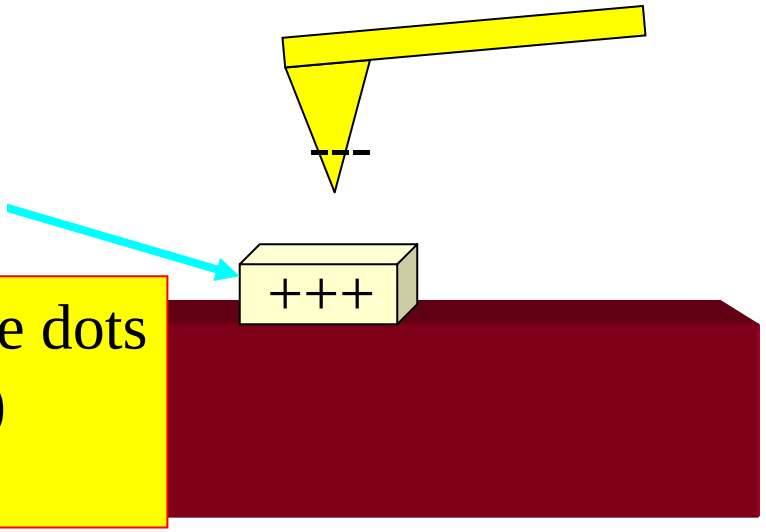
EFM signal
Charge detection



V=-6 V
t=10 s

X ray





Detection of charge induced by X ray in Ge dots at Ge absorption edge (see Ishi work)
Electrostatic Force Microscopy

Then thanks to AFM/X ray combination, you can try:

- to locally deform a single object and to probe it by X ray scattering *in situ and real time*

- to detect charged induced by X ray ionization (semiconductor)

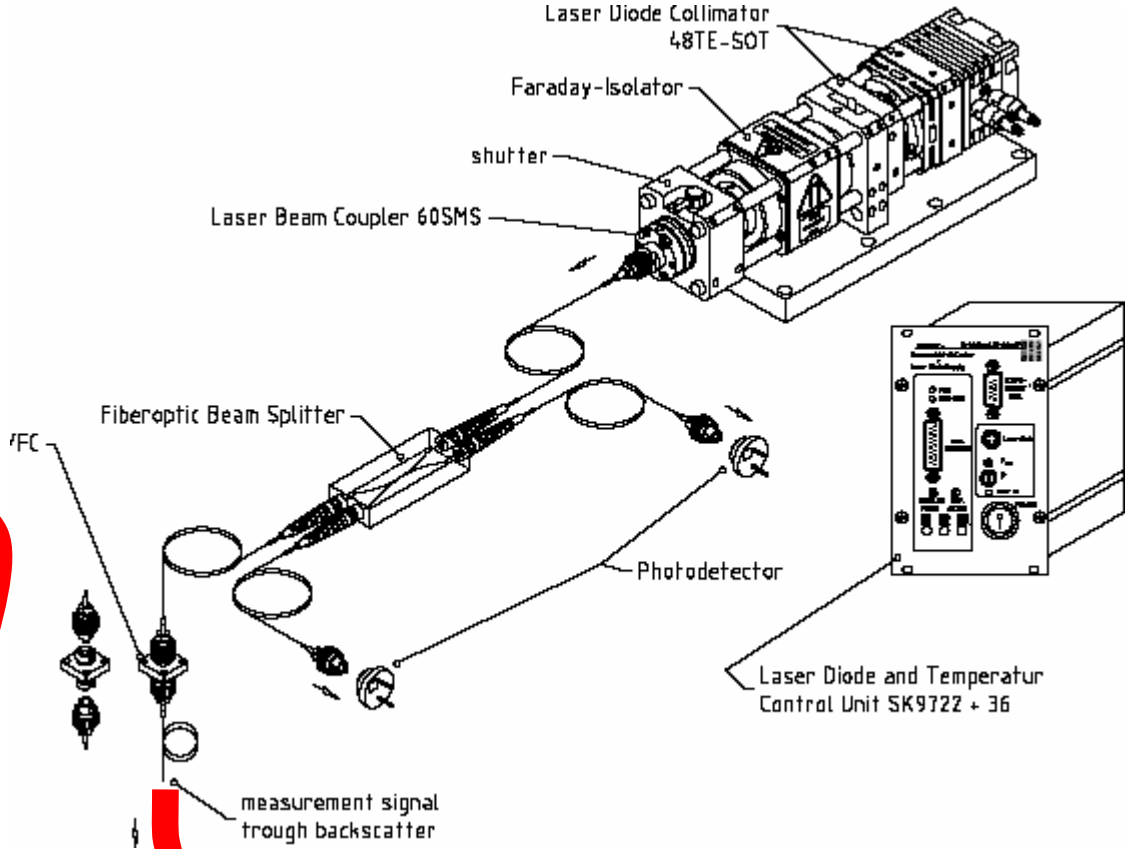
- to put little sample in the beam to study it: nanomanipulation

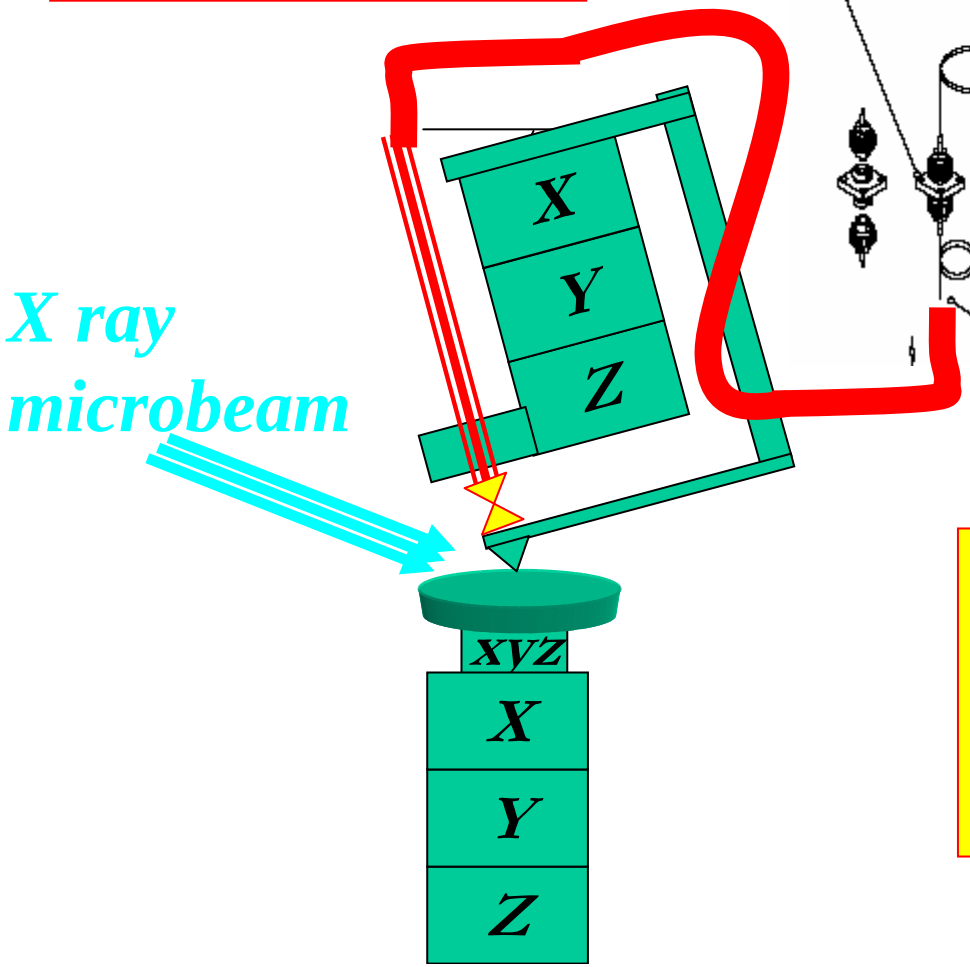
BUT...

Implementation of current AFM on beamline not easy….but can be done

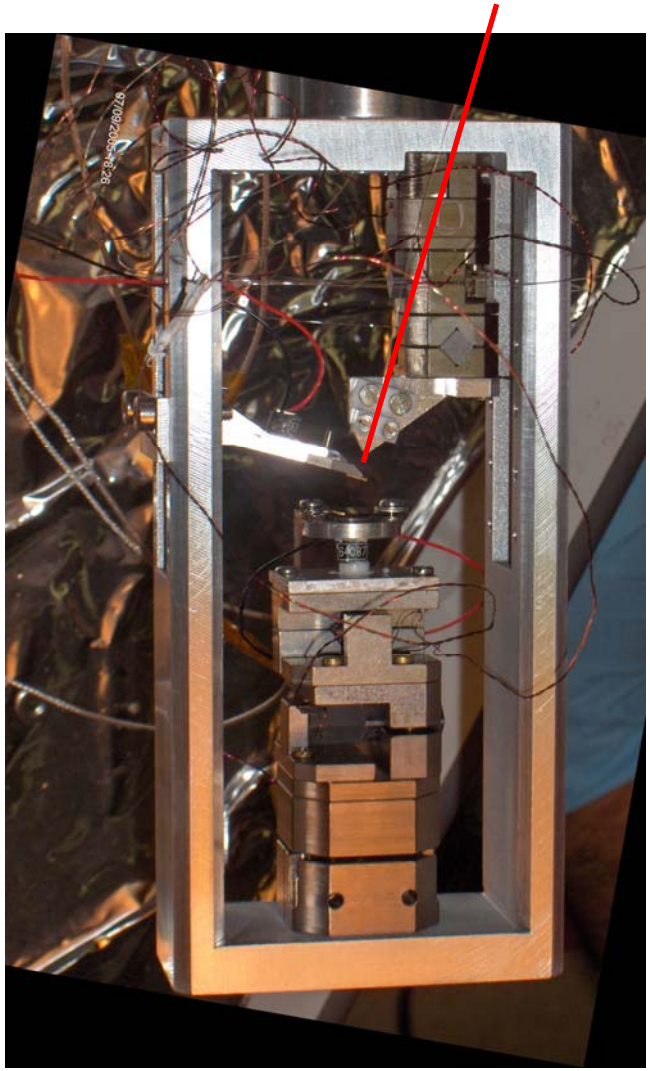
See Olivier Dhez talk already for *current detection*….

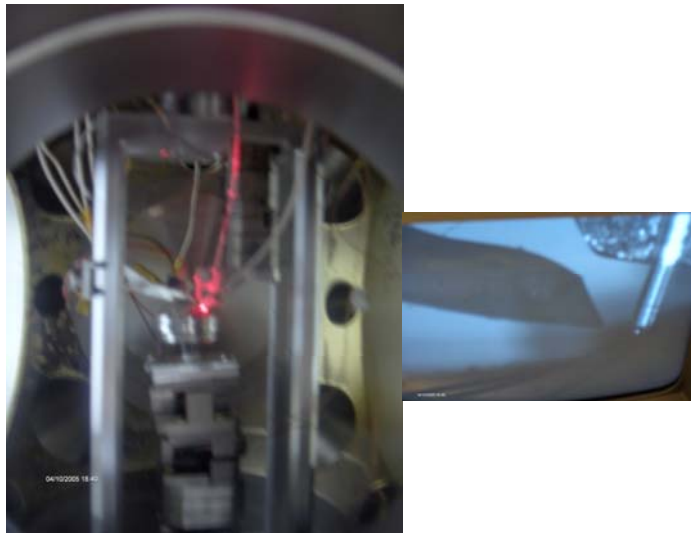
Fabry Pérot cavity:
combination X ray
force detection
nanopositioning
….

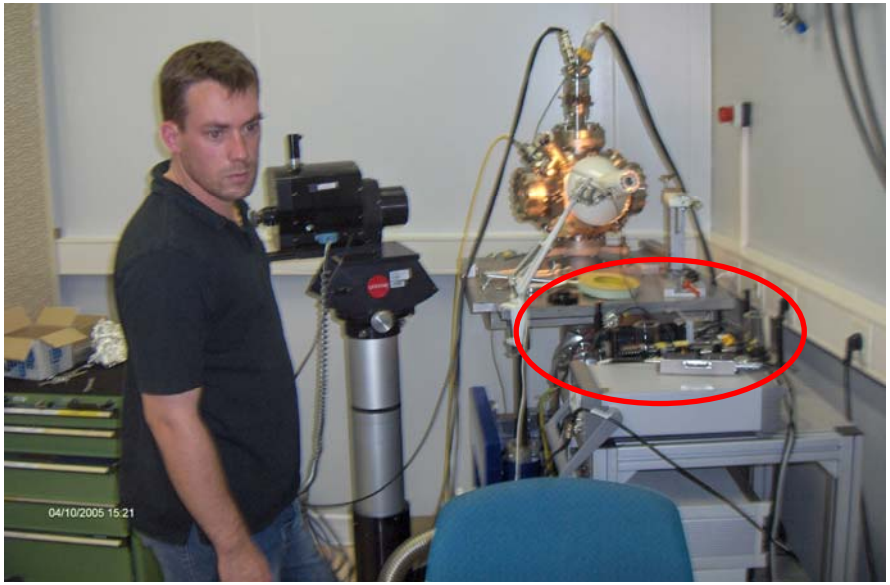




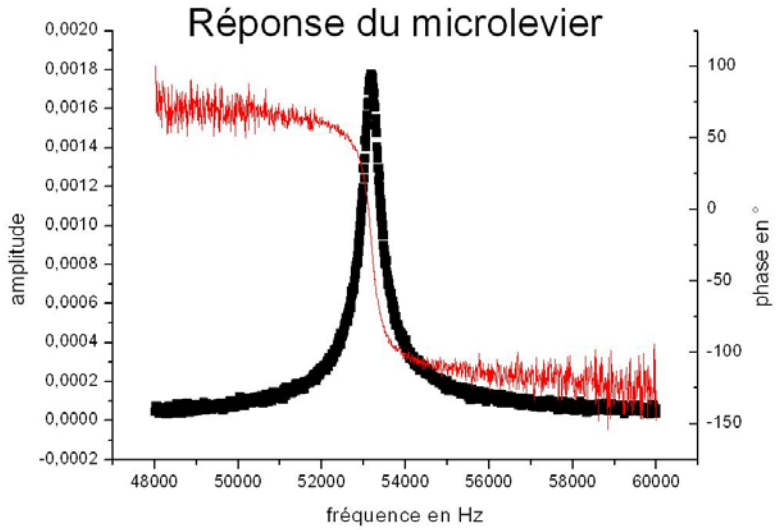
Lever position monitored
Fabry Perot cavity:
open space-compact system
no external optical system

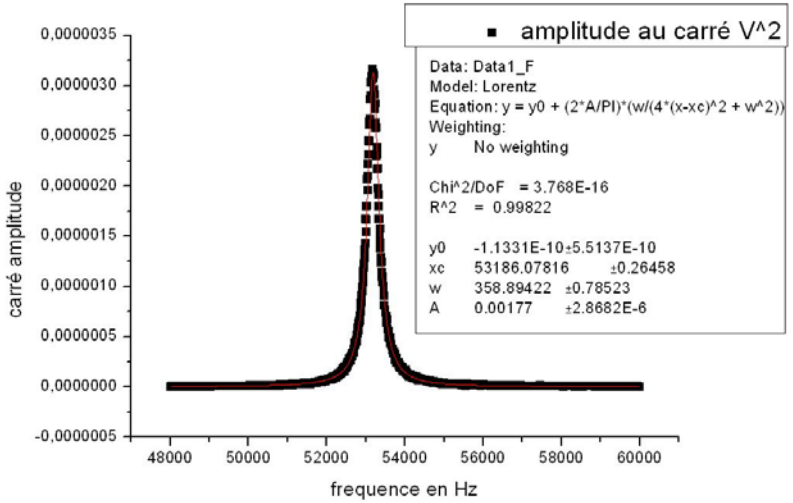






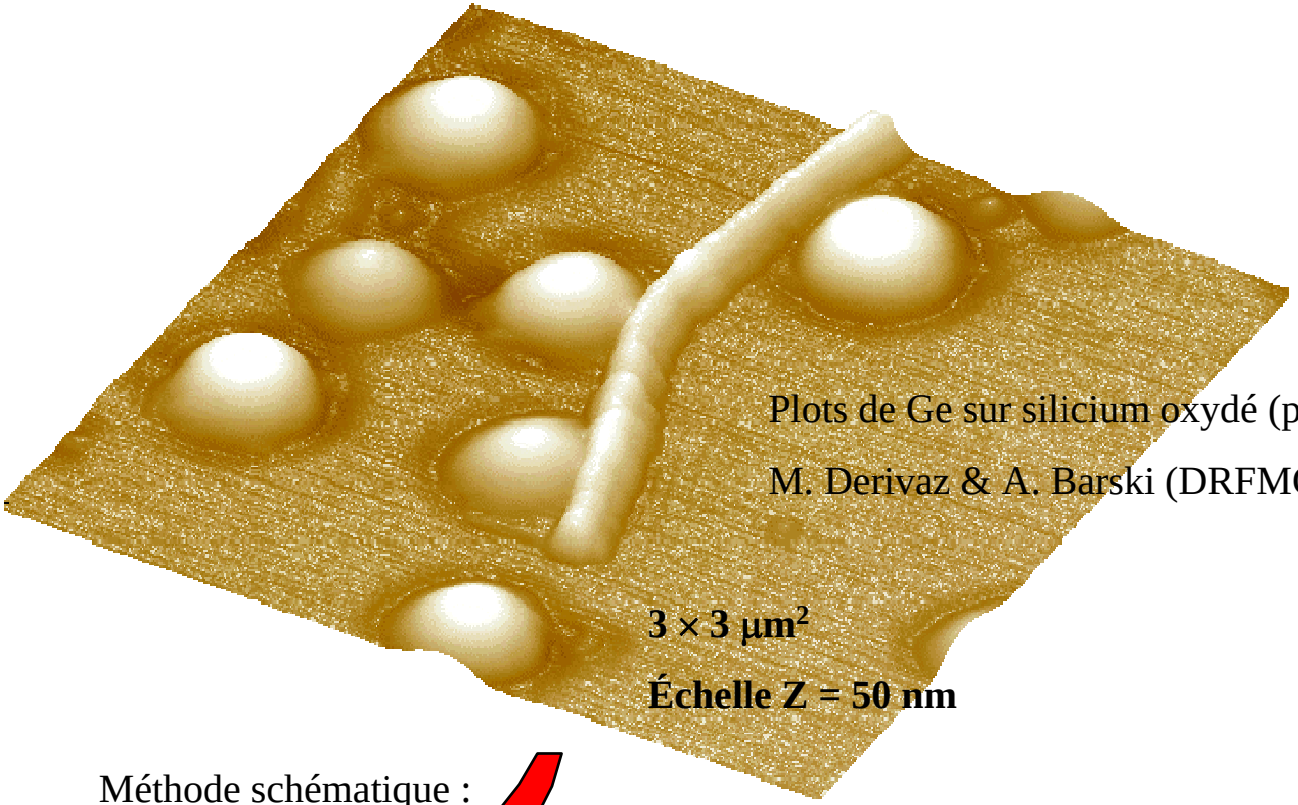
Coll. ESRF-LEPES-Spectro


Réponse du microlevier
amplitude
phase en °
fréquence en Hz
0,0020
0,0018
0,0016
0,0014
0,0012
0,0010
0,0008
0,0006
0,0004
0,0002
0,0000
-0,0002
100
50
0
-50
-100
-150
48000
50000
52000
54000
56000
58000
60000


amplitude au carré V^2
Data: Data1_F
Model: Lorentz
Equation: y = y0 + (2*A/PI)*(w/(4*(x-xc)^2 + w^2))
Weighting:
y No weighting
Chi^2/DoF = 3.768E-16
R^2 = 0.99822
y0 -1.1331E-10±5.5137E-10
xc 53186.07816 ±0.26458
w 358.89422 ±0.78523
A 0.00177 ±2.8682E-6
carré amplitude
frequence en Hz
0,0000035
0,0000030
0,0000025
0,0000020
0,0000015
0,0000010
0,0000005
0,0000000
-0,0000005
48000
50000
52000
54000
56000
58000
60000

Nanomanipulation

real time in situ controlled deformation of a nanoobject



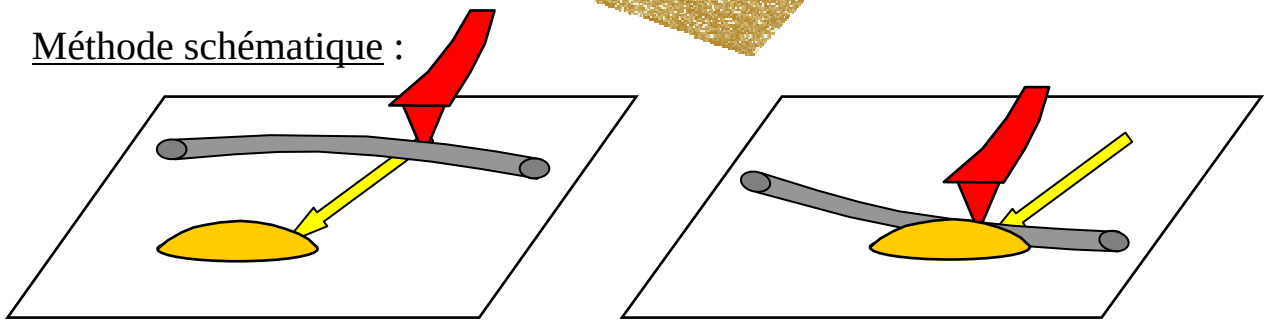
Plots de Ge sur silicium oxydé (par MBE)

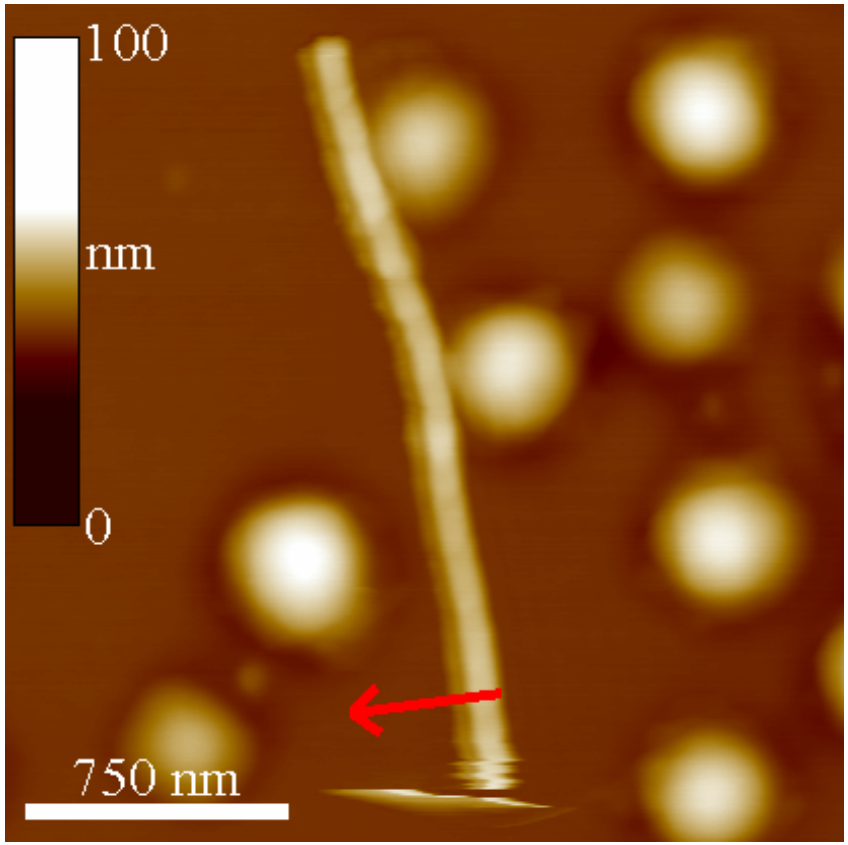
M. Derivaz & A. Barski (DRFMC/CEA)

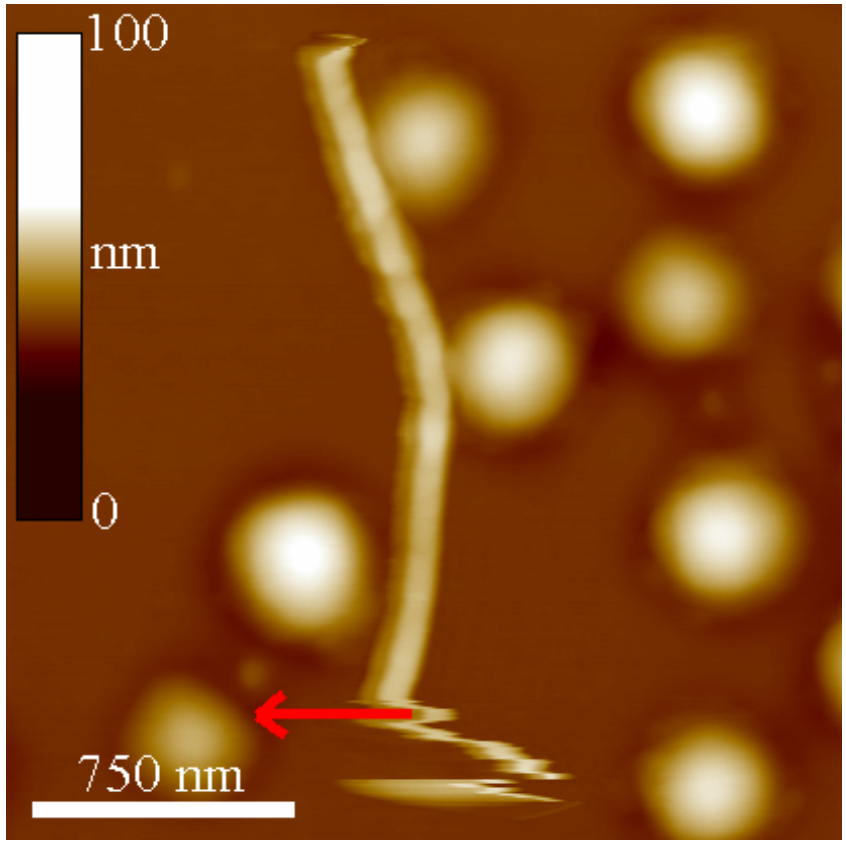
3 × 3 µm²

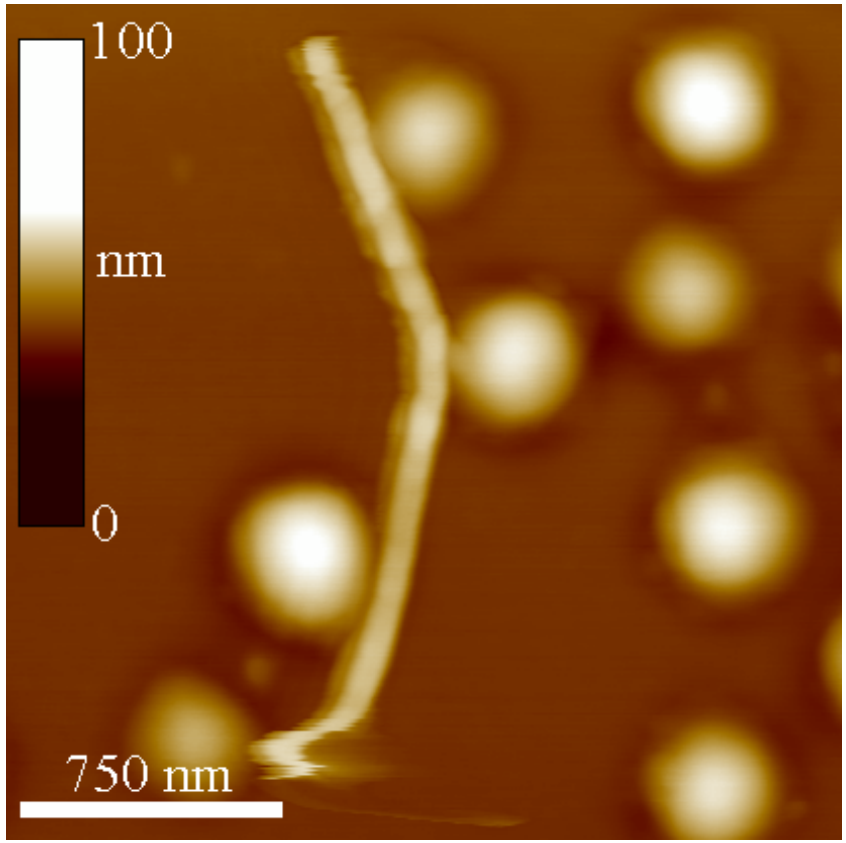
Échelle Z = 50 nm

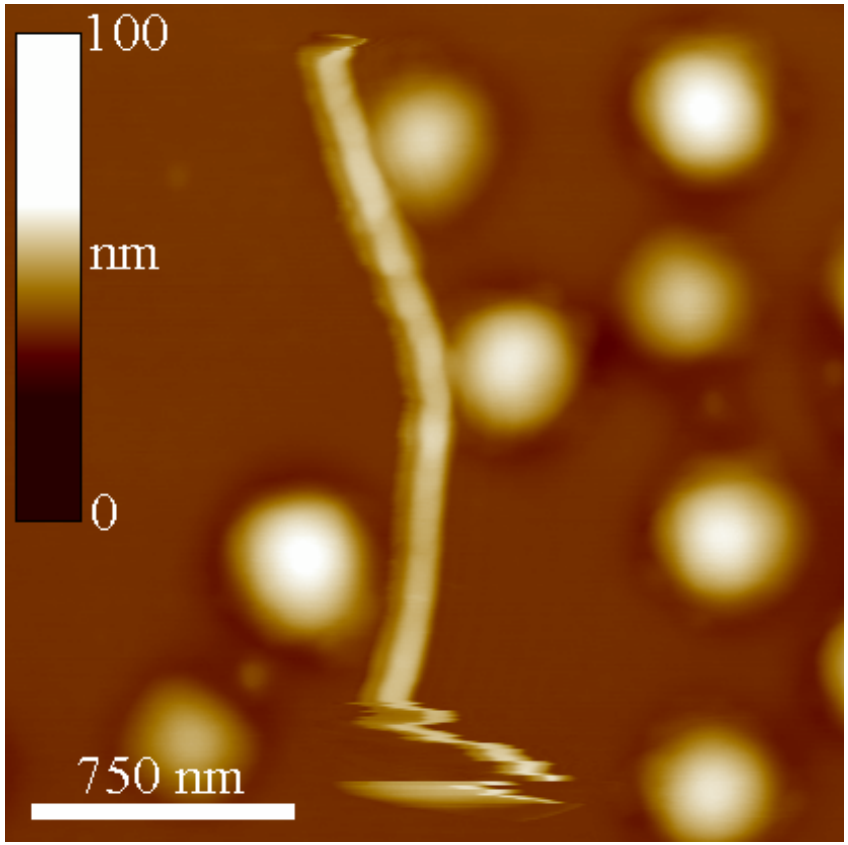
Méthode schématique :

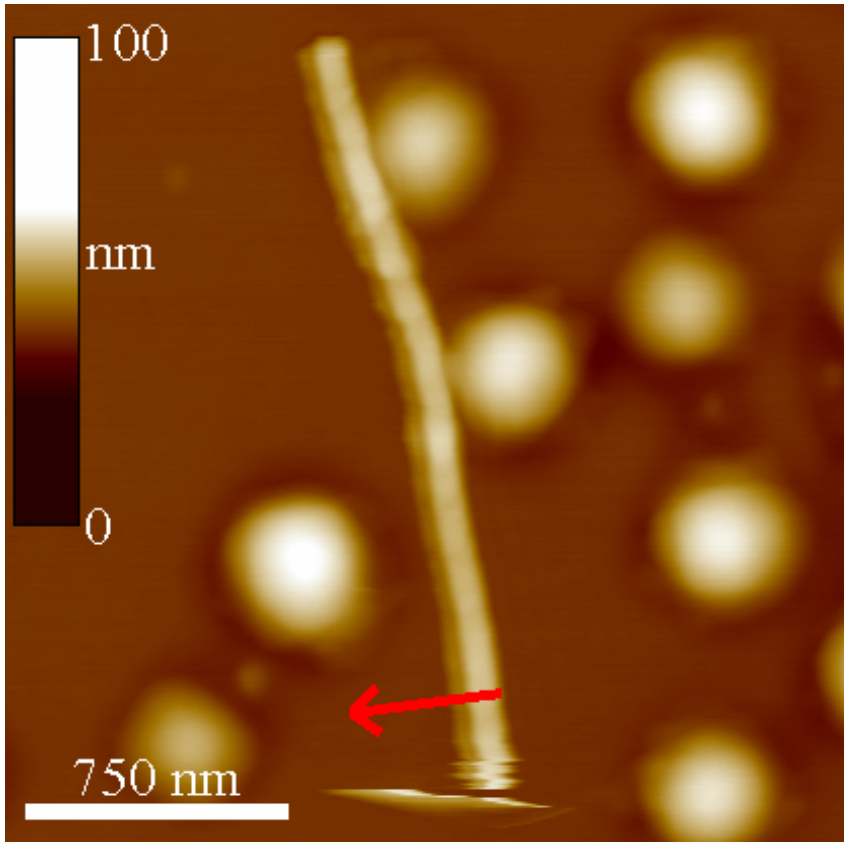


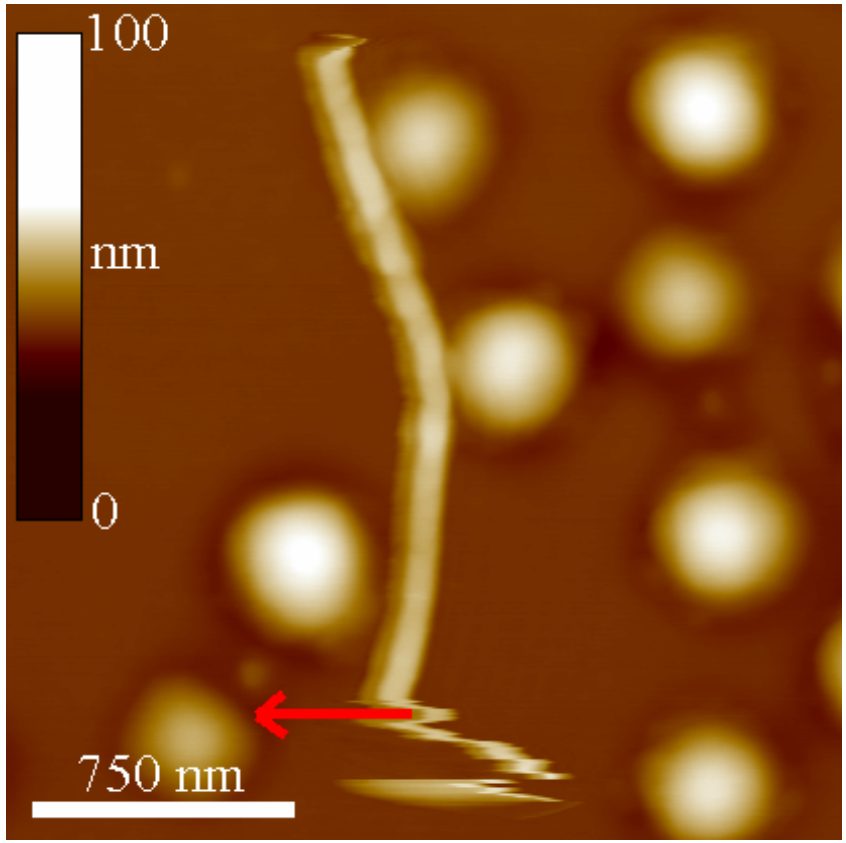

100
nm
0
750 nm

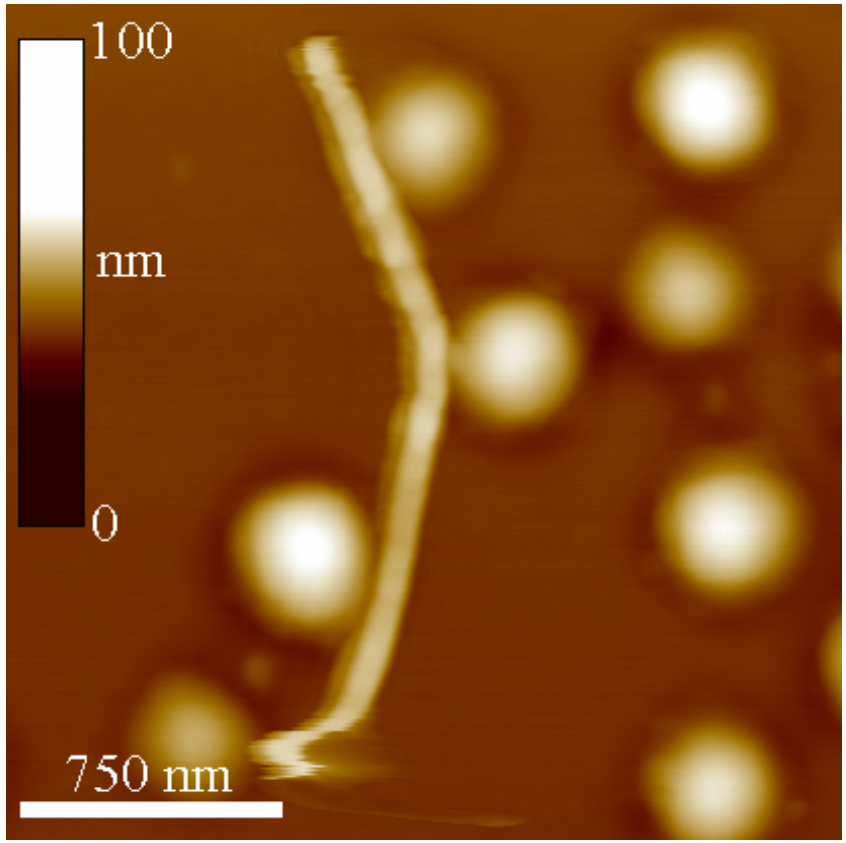

100
nm
0
750 nm

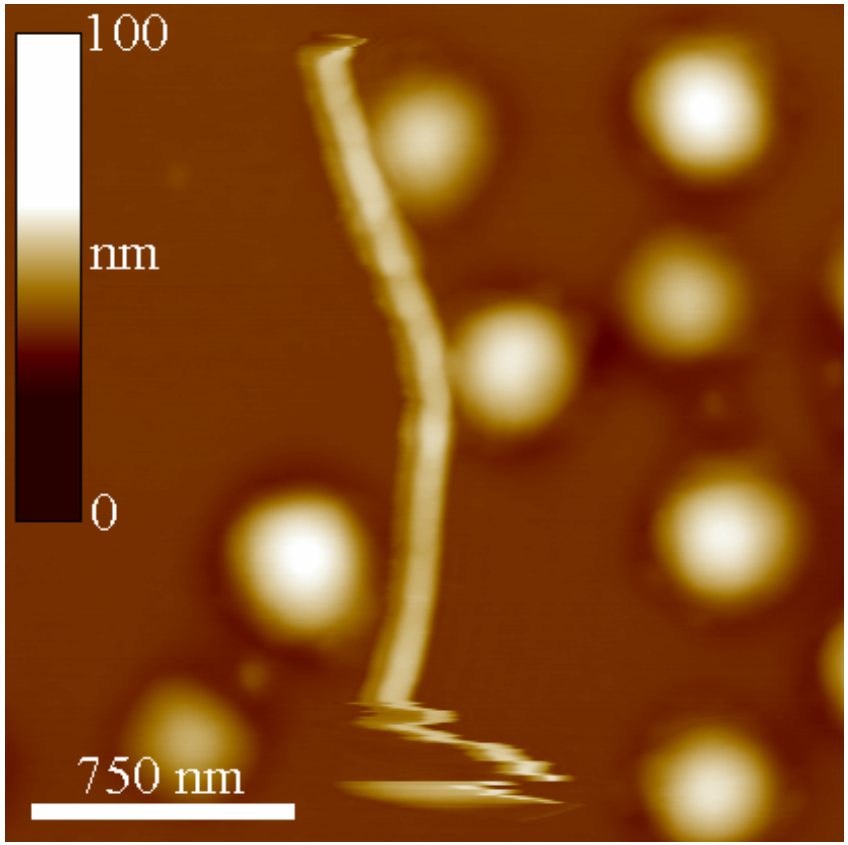

100
nm
0
750 nm

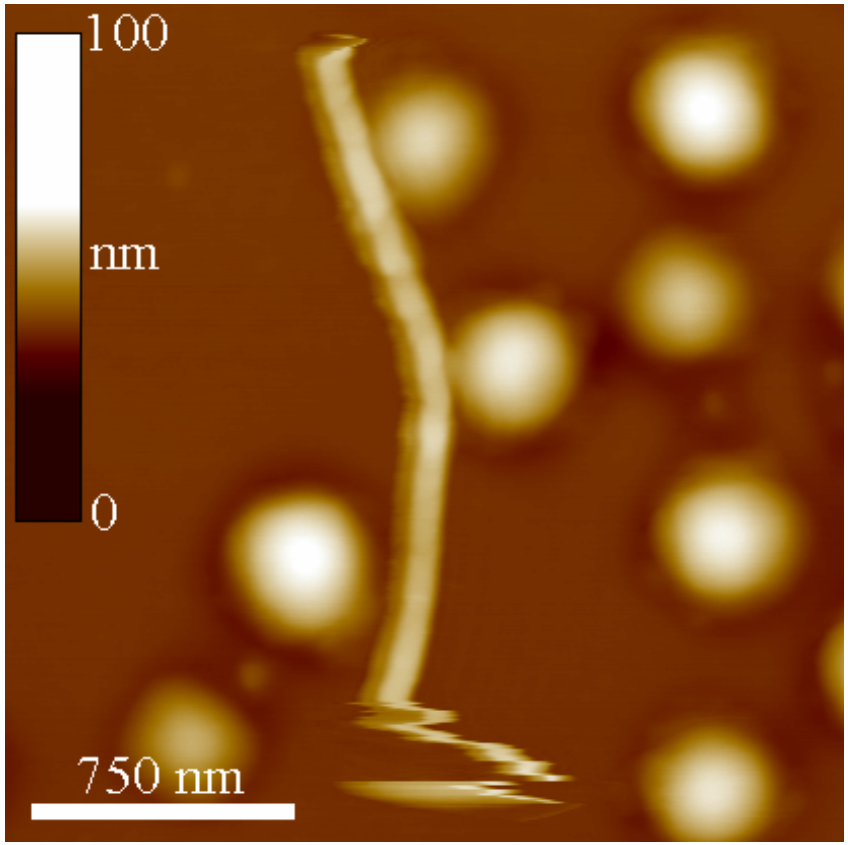

100
nm
0
750 nm


100
nm
0
750 nm

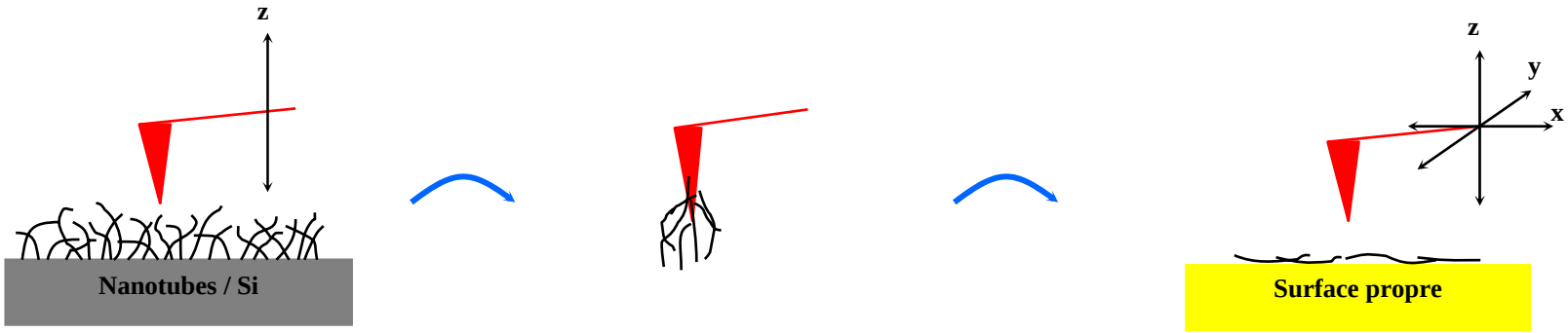

100
nm
0
750 nm

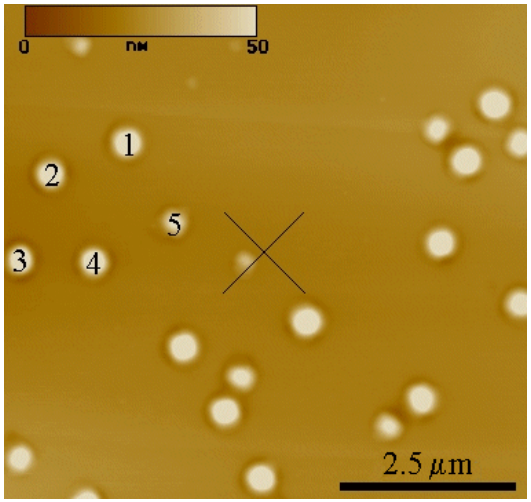

100
nm
0
750 nm


100
nm
0
750 nm

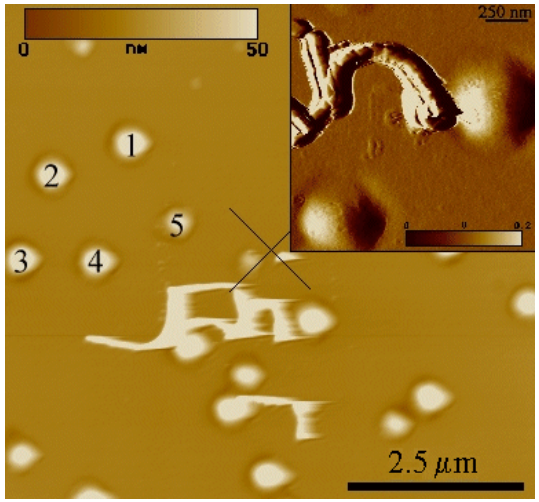

100
nm
0
750 nm

TRANSPORT and ABSOLUTE nanoPOSITIONING of Carbon nanotubes





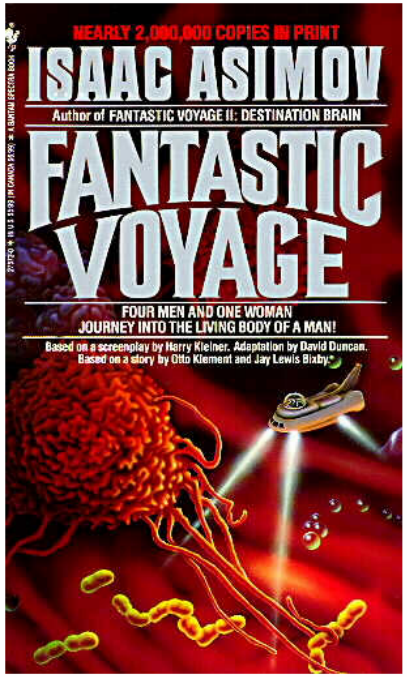
Before
contact mode

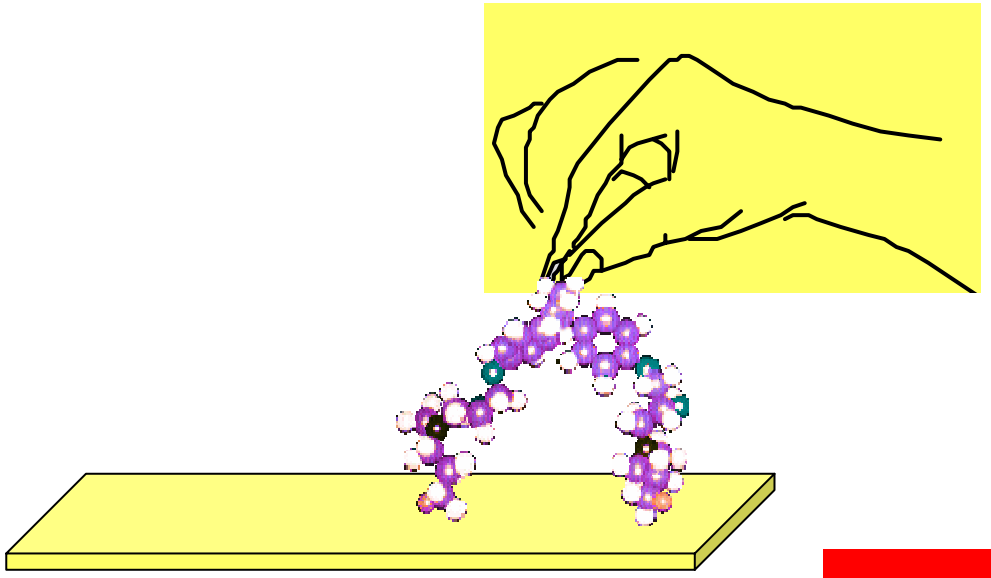


After
non contact mode

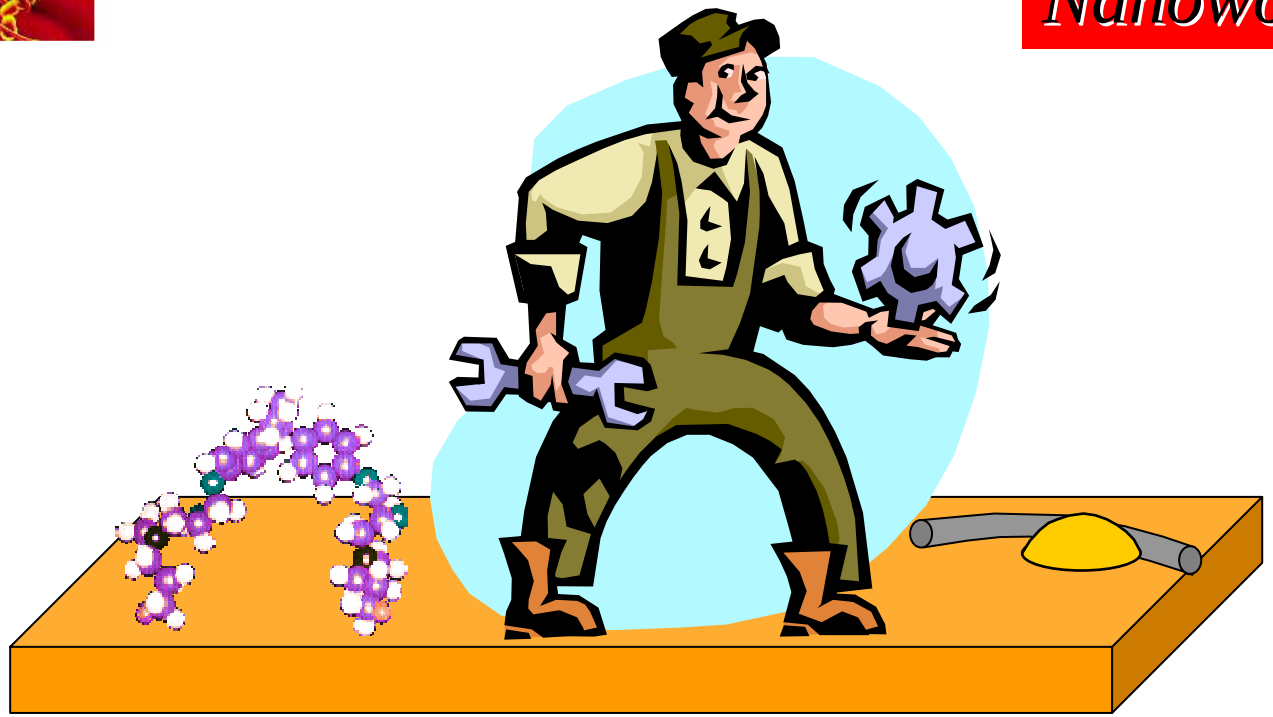
Deposition

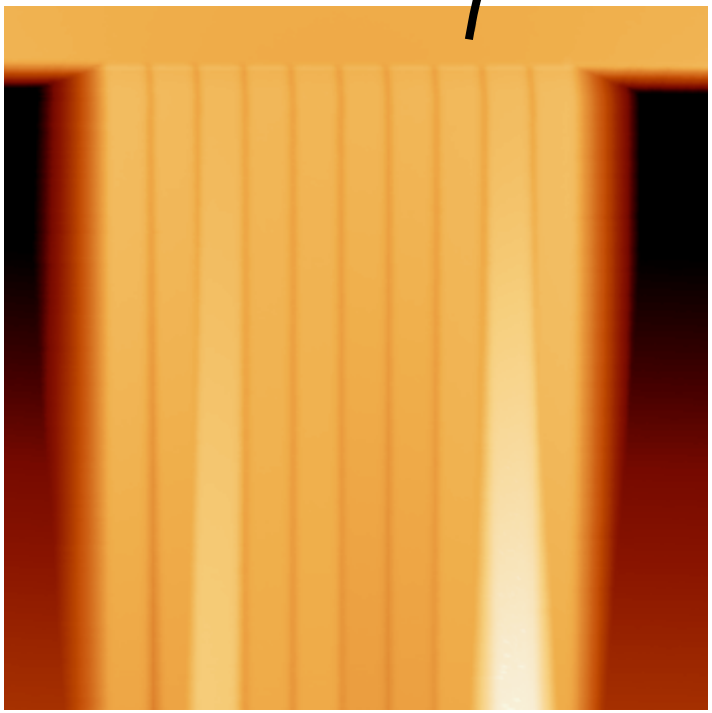
- Précision ≈ 300 nm


NEARLY 2,000,000 COPIES IN PRINT
ISAAC ASIMOV
Author of FANTASTIC VOYAGE II: DESTINATION BRAIN
FANTASTIC VOYAGE
FOUR MEN AND ONE WOMAN
JOURNEY INTO THE LIVING BODY OF A MAN!
Based on a screenplay by Harry Kleiner. Adaptation by David Duncan.
Based on a story by Otto Klement and Jay Lewis Bixby.

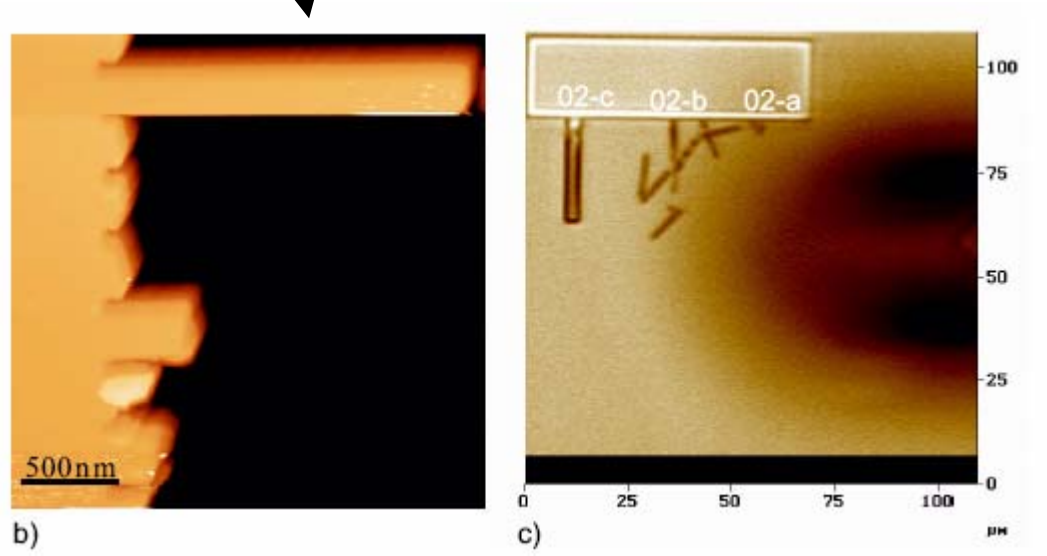


Nanoworld



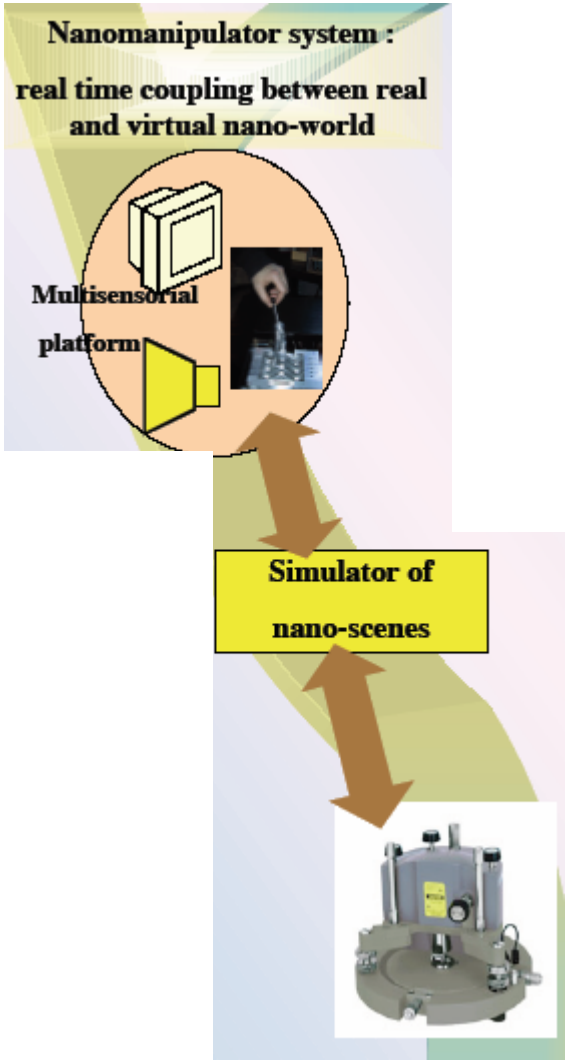


Careful AFM nanomanipulation of a LETI nanosystem



However….
Life can be somewhat tricky !!!

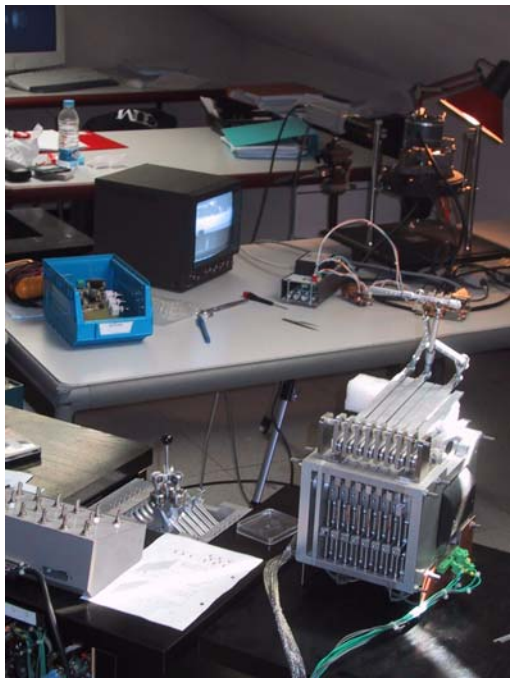
Direct human nanoobject link

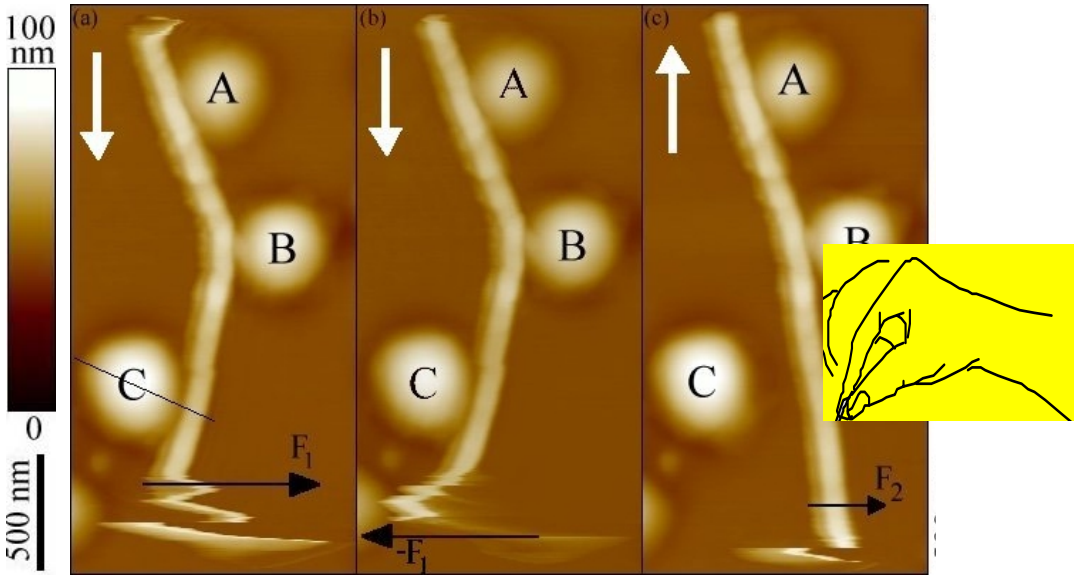


Force amplification 10^9

bandwith 3kHz

magnification of length nm to cm 10^7



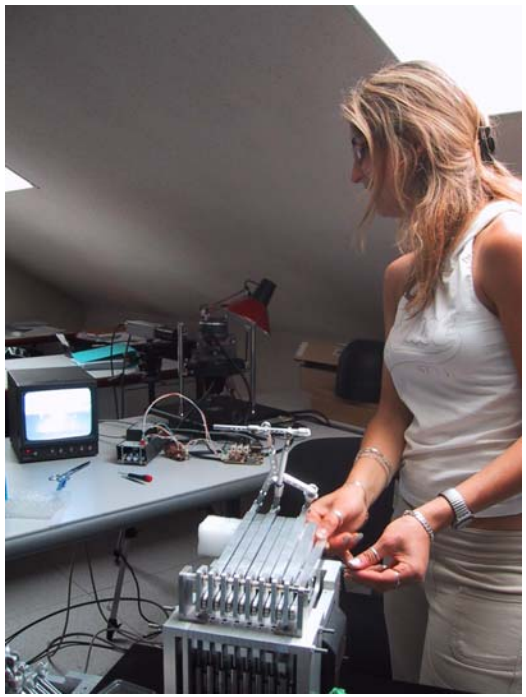


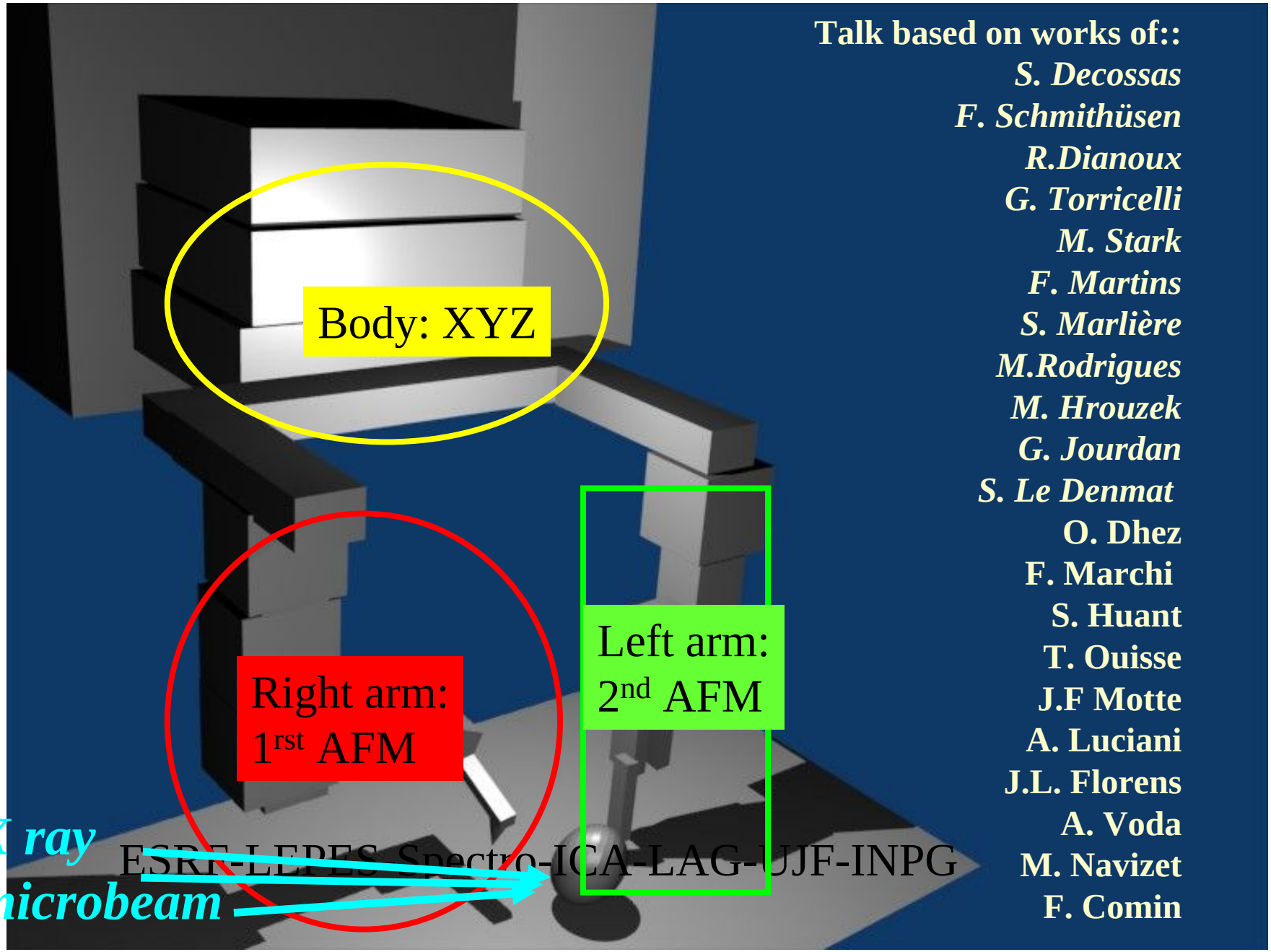
Here the basic manipulation is:

- pushing- pulling -

more is needed to truly manipulate micro/nanosample

say object with size 100nm-1μm and interaction control





Talk based on works of::

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